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RESEARCH PAPER

Impact of climate change on nutritional quality of maize and groundnut genotypes

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Abstract: An increase in atmospheric CO_2 concentration and temperature, together with other climate change factors could greatly affects agricultural productivity as well as quality of produce. Understanding the change in atmospheric CO_2 and temperature in conjunction with the ongoing global change is crucial to prepare for mitigation and any adoption for future agricultural production. Our study was mainly concentrated on response of maize and groundnut genotypes to climate change with respect to quality aspects. An experiment was conducted in Open Top Chambers (OTC's) at the Main Agricultural Research Station, University of Agricultural Science, Raichur. Two maize genotypes *i.e.* CP-818 and Hema and groundnut genotypes TMV-2 and K-9 were evaluated for two CO_2 levels (ambient CO_2 and elevated CO_2 @ 550 ppm) along with combination of temperature (ambient temperature and elevated temperature @ 2 °C) for *kharif* and *rabi* seasons of 2015. Results of the experiments were analysed through two factor-CRD design with 5 replications. Maize quality parameters like oil, protein and starch content were analysed by NIR Transmission at UAS, Raichur. Similarly for groundnut oil, protein content and fatty acid profile were analysed at IIOR, Hyderabad. The results showed that under elevated CO_2 @ 550 ppm condition, protein content in maize and groundnut was 8.1 and 19.8 per cent where as under ambient CO_2 condition it was 9.8 and 22.6 per cent. Carbon compounds (starch, oil content and fatty acids) increased under elevated CO_2 conditions. Oil content under elevated CO_2 condition of maize and groundnut was 6.7 and 49.4 per cent, whereas under ambient condition it was 6.6 and 45.5 per cent. The elevated temperature had negative effect on quality aspects (decreased protein, oil and fatty acid composition) of the crops.

Key words: Elevated temperature, Groundnut, Maize, Oil content

Introduction

Climatic variability, together with increase in atmospheric carbon dioxide (CO_2) and temperature have a lot of implications on agriculture sector. In recent decade, climate change resultant global warming has become an issue of serious concern worldwide for existence of life on earth. According to Intergovernmental Panel on Climate Change (IPCC), agriculture will inevitably face challenges caused by global climate change, which might lead to both global and local alteration. It has been reported by federal agencies that CO_2 concentration has increased by approximately 30 per cent since the industrial revolution, which is believed to be responsible for an increase of about 0.66 °C in mean annual global surface temperature. Meanwhile, the temperature is anticipated to increase further by 1.4 to 5.8 °C by 2100 with equally increasing atmospheric CO_2. According to IPCC (Anon., 2013) forecast models, the atmospheric CO_2, which is considered to be mainly responsible for the greenhouse effect, has increased from approximately 310 ppm in 1950 to about 404 ppm in the year 2016. This concentration is estimated to reach levels of 421-936 ppm by the end of 21st century (Anon., 2016). Climate is an important factor for agricultural productivity which has the fundamental role in human welfare. Concern has been expressed by many organizations and others regarding the potential effects of climate change on agricultural productivity. If current trends in global atmospheric change continue like this, by 2050, plants will be growing in an atmosphere with 50 per cent more CO_2 than the present CO_2 concentration (Betts *et al.,* 2007). For the past decade (2005-2014), on an average annual atmospheric CO_2 increase was 2.1 ppm per year (Anon., 2017).

Maize (*Zea mays* L.) is popularly known as "Queen of cereals" because of its higher yield potential among the cereals. Enhanced atmospheric CO_2 concentration influences the functions of ecosystem including agricultural yield. Global climate changes have led to increased temperatures, frequency of droughts and floods in one or the other parts of the world. It has been estimated that 2 °C increase in temperature above 30 °C reduces the maize yields by 13 per cent as compared to 20 per cent intra seasonal variation in the rainfall, which reduces the maize yields by 4.5 per cent. Further, every degree increase in day temperature above 30 °C would decrease yield by 1 per cent in optimum conditions and 1.7 per cent in drought conditions (Lobell *et al.,* 2011). Groundnut (*Arachis hypogaea* L.) is one of the major oilseed and food crops grown in subtropical and tropical regions of the world. The mean optimal air temperature range for vegetative growth of peanut is between 25 to 30 °C, which is warmer than optimum range for reproductive growth, which is between 22 and 24 °C.

The C_3 plants like groundnut responds better to atmospheric CO_2 enrichment than C_4 plants like in terms of increasing their rates of photosynthesis and biomass production. Among C_3 plants, legumes can supply nitrogen via symbiotic nitrogen fixation, expected to respond relatively more to a rise in CO_2 and increased temperature. Mize crop is called Biological

Cinderella of field crops and one of the important crops having C_4 mechanism. Keeping these views in mind, the present investigation was carried out with the objective to study the quality aspects of maize and groundnut under elevated CO_2 and temperature conditions.

Material and methods

Two maize genotypes (Hema and CP-818) were sown in each OTC and in reference plot during *kharif* season of 2015. Followed by two groundnut genotypes (TMV-2 and K-9) were sown in each OTC and in reference plot during *rabi* season of 2015 with ten plants were raised for each genotypes, and total 20 plants were in each OTC. All the agronomic practices followed for raising the crops.

Working principle and specifications of Open Top Chamber (OTC)

Open top chamber is the technology capable of providing means by which the environment around the growing plants may be modified to simulate future elevated concentrations of atmospheric CO_2 and elevated temperature. Four circular OTCs with dimensions of five meter diameter and four meter height constructed at the Main Agricultural Research Station, University of Agricultural Sciences, Raichur were used for the present study. The structure of OTCs were fabricated with aluminium round shaped frame installed on the ground covered with double walled 6 mm thick polycarbonate sheets which traps air within, providing thermal insulation and have more than 82 per cent transmittance of light. Chambers were equipped with a frustum at the top to deflect air and prevent dilution of the desired CO_2 concentrations within the chamber. The top of chamber was kept open to provide the near natural conditions.

Two OTC's were maintained at elevated conditions *viz.,* one with 550 ± 25 ppm CO_2 with 2 °C rise in temperature; another with 550 ± 25 ppm CO_2 with existing normal temperature. Other two OTCs were maintained at ambient conditions *viz.,* one with 390 ± 25 ppm CO_2 with 2 °Crise in temperature; a reference OTC with no elevation of CO_2 and temperature and a reference plot outside the open top chambers which served as untreated checks were maintained. To maintain the above said conditions, pure CO_2 mixed with ambient air was supplied to the chambers and maintained at set levels using manifold gas regulators, pressure pipelines, solenoid valves, rota meters, sampler, pump and CO_2 analyzer. The opening and closing of these valves were regulated on the basis of actual concentration of CO_2 within the OTC and the set CO_2 levels for that particular OTC which was regulated by Personal Computer (PC) through linked Program Logic Control (PLC) and Supervisory Control and Data Acquisition (SCADA) system. The temperature was maintained using infrared heaters mounted two meters above ground. The computer with uninterrupted power supply was established for uninterrupted data recording and storing. Each chamber was fitted with sensors to measure temperature and relative humidity and this facilitated the continuous monitoring of temperature (°C), CO_2 (ppm) and relative humidity (%) displayed on the monitor continuously.

Quality parameters of maize

Quality parameters are analyzed by the instrument NIR (Near Infrared Radiometer) Transmission analyser like protein (%), oil (%) and starch contents (%).

Quality parameters of groundnut

Oil content (%): Oil content was estimated on dry seed weight basis by using Nuclear Magnetic Resonance (NMR) spectrometer by using standard reference sample.

Protein content: Nitrogen content in seed of groundnut was estimated by Kjeldhal's method (Jackson, 1967). The protein per cent in seeds was calculated by multiplying the nitrogen content by factor of 6.25.

Fatty acid profile: Groundnut samples were sent to IIOR, Hyderabad for fatty acid estimation.

Results and discussion

Maize and groundnut plants grown under ambient CO_2 and ambient temperature recorded significantly higher crude protein (9.8 and 22.6 %, respectively) than rest of the treatments.

Table 1. Crude protein, oil and starch content in maize genotypes as influenced by elevated CO_2 and temperature in open top chambers during *kharif* 2015

Treatments	Crude Protein (%)			Oil (%)			Starch (%)		
	G_1	G_2	Mean	G_1	G_2	Mean	G_1	G_2	Mean
T_1	9.1	8.5	8.8	7.0	6.4	6.7	69.8	70.6	70.2
T_2	8.2	8.0	8.1	6.7	6.3	6.5	70.6	70.8	70.7
T_3	8.8	8.5	8.7	6.5	6.2	6.4	70.7	70.6	70.6
T_4	10.9	8.6	9.8	6.8	6.5	6.6	71.3	71.4	71.3
T_5	8.8	8.4	8.6	6.7	6.5	6.6	71.1	71.5	71.3
Mean	9.2	8.4		6.7	6.4		70.7	71.0	
	S.Em.±	C.D.@ 1%	C.D.@ 5%	S.Em.±	C.D.@ 1%	C.D.@ 5%	S.Em.±	C.D.@ 1%	C.D.@ 5%
Factor T	0.11	0.4	0.3	0.08	NS	0.2	0.9	NS	NS
Factor G	0.07	0.3	0.2	0.05	0.2	0.2	0.5	NS	NS
T x G	0.15	0.6	0.4	0.11	NS	NS	1.2	NS	NS

T_1 – eCO_2 (550ppm) + aTemperature, T_2 – eCO_2 (550ppm) + eTemperature (2^{0}C rise), T_3 – aCO_2 + eTemperature (2^{0}C rise), T_4 – Reference OTC, T_5 – Control plot, Maize: G_1 – Hema, G_2 – CP-818, Factor T- Climate variables effect, Factor G – Genotypic effect

Table 2. Crude protein and oil content in ground genotypes as influenced by elevated CO_2 and temperature in open top chambers during *rabi* 2015-16

Treatments	Protein content (%)			Oil content (%)		
	G_1	G_2	Mean	G_1	G_2	Mean
T_1	20.46	19.96	20.21	47.68	51.11	49.40
T_2	19.56	20.10	19.83	42.50	46.03	44.26
T_3	20.10	20.30	20.20	41.98	43.94	42.96
T_4	22.30	22.81	22.56	44.05	47.02	45.53
T_5	21.46	22.10	21.78	43.49	46.16	44.82
Mean	20.78	21.05	-	43.94	46.85	-
	S.Em±	C.D. @ 1%	C.D. @ 5%	S.Em±	C.D @ 1%	C.D. @ 5%
Factor T	0.24	0.93	0.69	0.51	1.96	1.46
Factor G	0.15	NS	NS	0.32	1.24	0.92
T x G	0.34	NS	NS	0.72	NS	NS

T_1 - eCO_2 (550ppm) + aTemperature, T_2 - eCO_2 (550ppm) + eTemperature(2^0C rise), T_3 - aCO_2 + eTemperature(2^0C rise), T_4 - Reference OTC, T_5 - Control plot, Groundnut: G_1 - TMV-2, G_2 - K-9, Factor T- Climate variables effect, Factor G -Genotypic effect

However, plants grown under elevated CO_2 @ 550 ppm with elevated temperature @ 2 °C rise recorded significantly lower crude protein (8.1 and 19.8 %, respectively). This is due to the most influencing factor for reduction in grain protein is nitrogen content in grain. Under elevated CO_2 condition grains might have assimilated more carbon; as a result there will be widening of C:N ratio was noticed (Sreedevi *et al.,* 2015). It was also noticed that a strong relationship exists between relative effects of elevated CO_2 as compared to ambient CO_2 on grain N and grain yield. This would be consistent with the dilution effect of N due to elevated CO_2. Further, which stimulated accumulation of more biomass in vegetative parts (Gifford *et al.,* 2010).

Maize and groundnut plants grown under elevated CO_2 @ 550 ppm and ambient temperature recorded significantly higher oil content (6.7 and 49.4 %, respectively) than rest of the treatments. However, plants grown under ambient CO_2 with elevated temperature @ 2 °C rise recorded significantly lower oil content (6.4 and 43.0 %, respectively).

However, interactive effect between genotypes with change in CO_2 levels and temperature variations on grain oil content of both the crops are found to be non-significant. Oils are primarily made up of fatty acids. Since fatty acids are mainly composed of carbon compounds this might have lead to increase in little increase in oil content of the groundnut. Increased oil content under elevated CO_2 is positive effect, as it could provide the thermo-stability to edible oil which is desirable from nutritional point of view (Yadav *et al.,* 2011).

Among the maize genotypes Hema recorded significantly higher protein and oil content (9.2 and 6.7 %, respectively) as compared to CP-818 (8.4 and 6.4 %, respectively). Between the groundnut genotypes, K-9 has recorded significantly higher grain oil and protein content (46.9 and 21.1 %, respectively) as compared to genotypes TMV-2 (44.0 and 20.8 %, respectively).

The highest starch content was recorded in ambient carbon dioxide with ambient temperature treatments *i.e.* T_4 (71.3 %) and T_5 (71.3 %) treatments, respectively. Least starch content of grain was recorded in elevated CO_2 @ 550 ppm with ambient temperature T_1 (70.2 %). Between the genotypes, Hema recorded lower starch content (70.7%) than CP-818 genotypes (71 %). The CO_2 enrichment enhances the accumulation of carbon containing compounds, such as starch, sucrose and hexoses. High temperature had little effect on enzyme invertase and sucrose synthase but activities of ADP glucose pyrophosphory lase, starch synthase and starch branching enzyme were not affected (Kavita *et al.,* 2011). Elevated temperatures enhances partitioning of both transitory and storage starch (Prasad *et al.,* 2005).

Fatty acid profile: The fatty acid profile of groundnut genotypes as influenced by elevated CO_2 and temperature in open top chambers (Table 3) reveals that, highest oleic acid (18.78%) noticed with TMV-2 in T_4 (Reference OTC) and lowest (10.82%) was recorded with same variety in T_2 (eCO_2 @ 550 ppm with eTemperature @ 2 °C rise). Whereas, highest linoleic acid (56.61 %) was recorded with K-9 in T_3 (aCO_2 with eTemperature of 2 °C rise) and lowest (43.77 %) was recorded with TMV-2 variety in T_4 (Reference OTC). Among the genotypes, K-9 has

Table 3. Fatty acid profile of groundnut genotypes as influenced by elevated CO_2 and temperature in open top chambers conducted during *rabi* 2015

Treatment	Genotype	Palmitic acid (%)	Stearic acid (%)	Oleic acid (%)	Linoleic acid (%)	Arachidic acid (%)	Elicosaenic acid (%)	Behenic acid (%)
T_1	TMV-2	0.98	0.34	16.09	43.87	36.31	1.47	0.93
	K-9	3.47	1.26	11.93	50.66	29.94	1.37	1.37
T_2	TMV-2	0.54	0.28	10.82	47.92	38.00	1.46	0.98
	K-9	0.52	0.16	13.09	55.46	28.10	1.40	1.27
T_3	TMV-2	3.13	0.99	14.75	44.53	34.20	1.39	1.03
	K-9	0.14	0.06	12.72	56.61	28.55	1.08	0.84
T_4	TMV-2	0.59	0.24	18.78	43.77	34.93	1.16	0.53
	K-9	2.60	0.93	15.65	50.41	28.76	1.06	0.60
T_5	TMV-2	0.09	0.05	16.31	44.35	36.55	1.65	1.00
	K-9	1.05	0.32	13.22	53.85	29.63	1.19	0.73

T_1 – eCO_2 (550ppm) + aTemperature, T_2 – eCO_2 (550ppm) + eTemperature(2^0C rise), T_3 – aCO_2 + eTemperature(2^0C rise), T_4 – Reference OTC, T_5 – Control plot, G_1 – TMV-2, G_2 – K-9, Factor T- Climate variables effect, Factor G – Genotypic effect recorded higher palmitic, stearic, linoleic and behenic acids, whereas TMV-2 has recorded higher oleic, archidic and elicosaenic acids irrespective of variations in CO_2 and temperature.

Conclusion

Climate is the primary determinant of plant growth, its development, yield and quality. Extent as well as amount of carbon dioxide and optimum temperature decides the crops characters. Different levels of CO_2 and temperature significantly influenced on different quality parameters of maize and groundnut like protein, oil, starch and fatty acid content. Similarly, maize genotypes (Hema and CP-818) and groundnut genotypes (TMV-2 and K-9) showed variations in results. The elevated CO_2 and temperature leads to decrease in nitrogen related compounds like protein but oil and starch content was increased under elevated CO_2 condition. Response differed between genotypes too. In case of maize Hema performance was good as compared to CP-818 and in case of groundnut K-9 performance was good as compared TMV-2.

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